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METHOD FOR MANUFACTURING A POLYCRYSTALLINE SEMICONDUCTOR THIN FILM
[Takessho Handotai Usu Maku no Seizo Hoho]

Akihiro Oda, Yoshiki Kojima, and Ito Masataka

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Inventors	:	Akihiro Oda, Yoshiki Kojima, and Ito Masataka
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Specification /1[1]

(54) Title of the Invention: METHOD FOR MANUFACTURING A POLYCRYSTALLINE SEMICONDUCTOR THIN FILM

(57) Summary

Objective: Its objective is to provide a method for preparing a thin film transistor which exhibits a high action speed in an active matrix-type liquid crystal display, etc. with a large area not only homogeneously but also in a high throughput.

Constitution: The laser intensity distribution in the laser anneal method is rectified at a certain homogeneous width, and after annealing has been performed, a striped polycrystalline semiconductor layer with a homogeneous crystallinity can be obtained. The throughput, too, is improved by forming such striped polycrystalline semiconductor layers in necessary areas alone and by integrating the transistors of pixel units and drive circuit sections with the interior of said stripes.

Claim /2

A method for manufacturing a polycrystalline semiconductor thin film with the following characteristics: In a method for manufacturing a polycrystalline semiconductor thin film wherein

[1]Numbers in the margin indicate pagination in the foreign text.

an amorphous silicon film formed above a glass substrate is annealed by irradiating a laser beam, said laser beam is rectified in such a way that its intensity will become constant at a width larger than the width of a thin film transistor row formed above said glass substrate, and said non-crystalline [sic] semiconductor is annealed in a striped pattern with a certain width while said laser beam or glass substrate is being transported.

Detailed explanation of the invention

[0001]

(Industrial application fields of the invention)

The present invention concerns a method for manufacturing a silicon semiconductor thin film with an excellent crystallinity which exhibits homogeneous performances above a glass substrate at a constant width. More specifically, it concerns an active matrix-type liquid crystal display which forms a thin film transistor (hereafter referred to simply as the "TFT") by using said silicon semiconductor thin film.

[0002]

(Prior art of the invention)

Active matrix-type liquid crystal displays equipped with thin film transistors which possess amorphous silicon (hereafter referred to simply as "a-Si") semiconductor films have been developed for practical purposes. Transparent substrates such as glasses, quartz, etc. are being used as substrates of such

displays. In particular, inexpensive glass substrates are desirable for enlarging the area.

[0003]

Attempts have been made to form a TFT drive circuit above the glass substrate while an a-Si TFT is being simultaneously formed. Polycrystalline thin film transistors (hereafter referred to simply as the "poly-Si TFT"), the action speeds of which are high, must be employed as such drive circuits.

[0004]

Annealing treatments which utilize laser beams have heretofore been performed for obtaining polycrystalline silicon (hereafter referred to simply as the "poly-Si") layers with excellent crystallinity as TFT active layers by means of a low-temperature process at a temperature equal to or lower than the glass strain point. In particular, the following method is known as a method which utilizes continuously oscillated (CW) lasers: After an a-Si layer has been formed above a glass substrate, a laser beam with an output of several W is collected and irradiated on said film at a diameter of several dozen to several hundred μm, and overlapping scanning actions are invoked at a gap width of several dozen μm while the laser beam or substrate is being transported, as a result of which the entire substrate is annealed, and the a-Si layer is polycrystallized.

[0005]

Since overlapping scanning actions are invoked at an interval of several dozen μm during the annealing sequence,

however, the crystallinities differ in a segment in which overlapping beams are scanned and in a segment in which non-overlapping beams are scanned, and accordingly, the performances of a TFE formed in the segment in which overlapping beams are scanned and in the segment in which non-overlapping beams are scanned inevitably differ.

[0006]

A method wherein a TFT active layer region alone is laser-annealed has been proposed for solving this problem and for improving the throughput (see M. Yuki and K. Masumo, IEEE Electron Device, Vol. 36, No. 9, p. 1934, 1989). In this method, a striped poly-Si layer with a width of 30 μm is obtained by the laser beam method, and a TFT active layer is formed in this poly-Si layer alone, as a result of which the beam overlap problem and throughput problem are solved.

[0007]

(Problems to be solved by the invention)

The laser beam intensity of the poly-Si film formed in the aforementioned method, however, is characterized by a Gauss distribution, and accordingly, its crystallinity is also characterized by a distribution concordant with said intensity distribution. For this reason, it is impossible to sufficiently improve the TFT performances, which is problematic. If the laser beam width is enlarged for simultaneously annealing two or more TFT rows, furthermore, the crystallinity distribution is concomitantly broadened.

[0008]

The objective of the present invention, which has been proposed for solving the foregoing problem, is to provide a method for preparing a TFT with a high action speed used for an active matrix-type liquid crystal display, etc. with a large area not only homogeneously but also in a high throughput by forming a poly-Si film with a homogeneous crystallinity at least in a region where a TFT is formed.

[0009]

(Mechanism for solving the problems)

The optical system of the present invention is embodied in such a way that a homogeneous intensity distribution will be achieved in a direction perpendicular to the laser beam scanning direction. The width over which such a homogeneous intensity distribution is achieved is larger than [the width of] the TFT, and in a desirable embodiment, two or more TFT rows are included. After an a-Si film formed above a glass substrate has been annealed by irradiating said laser beam, a striped poly-Si layer with homogeneous performances is formed. Moreover, a TFT is prepared within said striped poly-Si layer.

[0010]

In a case where an active matrix-type liquid crystal display is prepared, the positions of pixels and drive circuit transistors are confined within the width of the striped poly-Si layer, and no beams are irradiated on unnecessary areas.

[0011]

(Functions of the invention)

Since the laser beam is characterized by a homogeneous intensity distribution in a direction perpendicular to the scanning direction and since the thermal insulating capacity of the glass substrate is high, a striped poly-Si layer with a high crystallinity which exhibits virtually homogeneous performances over the laser beam width, which is characterized by said homogeneous intensity distribution, can be obtained if the a-Si formed above the glass substrate is laser-annealed.

[0012]

The laser beam scanning position is adjusted in such a way that said striped poly-Si layer will coincide with the TFT row. If the laser beam width over which the intensity distribution is homogeneous is enlarged, it becomes possible to anneal two or more TFT rows simultaneously, and as a result, the throughput can be improved.

[0013]

(Application examples)

The present invention will be explained with reference to figures pertaining to an application example of an active matrix-type liquid crystal display. /3

[0014]

Figures 1 show cross-sectional views of processes for forming striped poly-Si layers above a glass substrate and for subsequently preparing a TFT.

[0015]

(a): After the SiO_2 film (2), the thickness of which is approximately 5,000 Å, has been formed above the glass substrate (1), the a-Si film (3), the thickness of which is approximately 1,000 Å, is formed above said SiO2 film (2). Moreover, the SiO_2 film (4), which serves as an antiglare film, is formed above said a-Si film (3).

[0016]

(b): Next, the a-Si film (3) is crystallized and annealed by irradiating an Ar ion CW laser, and as a result, the poly-Si layer (5) is formed. In such a case, either the laser or substrate is transported, as Figure 2 (a) indicates, in such a way that the laser will be irradiated on the segment corresponding to the region (22) and that the striped poly-Si layer (5) will be formed.

[0017].

The laser beam used for the laser-annealing purpose of the present invention is rectified by using the optical system shown in Figure 3 in such a way that a homogeneous intensity distribution with a constant width will be achieved. In the case of the TEM_{00} mode, the output beam (30) of the Ar^+ laser is characterized by the Gauss distribution shown on the left fringe of Figure 3.

[0018]

This beam (30) is split into two beams (35) and (36) by using the Fresnel's biprism (31). These two beams (35) and (36)

are transmitted through the lenses (32) and (33), respectively, and then overlapped on the irradiation plane (34). Figure 4 shows a state where the beams have been overlapped on the irradiation plane. The beams (36) and (37), which are indicated by dotted lines, are obtained by overlapping beams obtained by splitting [a beam with] a Gauss distribution into two at the center. As the solid line (41) indicates, a region in which the intensity is constant over the width t can be obtained by optimizing the focal distances of the lenses (32) and (33) and the distances among the Fresnel's biprism (31) and the lenses (32) and (33).

[0019]

The intensity distribution is homogenized over the width t, and accordingly, the poly-Si crystallinity is homogenized over this range. The range of the width t is 1500-500 μm within laser power and scanning speed ranges of 10-20 W and 20-200 mm/s, respectively, in a case where the focal distances of the lenses (32) and (33) and the distances among the Fresnel's biprism (31) and the lenses (32) and (33) are optimized.

[0020]

The pixel pitch of the active matrix-type liquid crystal display is approximately 100 μm, and therefore, two to five rows can be annealed by a single scanning cycle.

[0021]

In addition to the optical system shown in Figure 3, a laser beam with a homogeneous intensity distribution can be obtained by

overlapping laser beams with two Gauss distributions by using a reflective mirror in such a way that the distribution shown in Figure 5 will be achieved on the irradiation plane.

[0022]

Subsequently, the SiO_2 film (4) is removed.

[0023]

(c): Next, the resulting striped poly-Si layer (5) is patterned into the island-shaped layer (6) photolithographically (Figure 2 (b) is a diagram which shows a plane view of Figure 1 (c)).

(d): A TFT is subsequently prepared by an ordinary process (Figure 2 (c) is a diagram which shows a plane view of Figure 1 (d)). The following, although no detailed process explanations are provided [sic: Incomplete sentence]. The source region (8) and the drain region (9) are formed on the island-shaped poly-Si layer (6), and the gate insulating film (7) is laminated on top of the resulting structure. After the gate electrode (11) has been formed above it by means of patterning, the interlayer insulating film (14) is coated, and after a throughole has been drilled on said interlayer insulating film (14), the source electrode (12) and the drain electrode (13), which are contacted with the source region (8) and drain region (9), respectively, are configured.

[0024]

A case where a single TFT row is prepared by using a singular striped poly-Si layer has been explained with reference

to Figures 1. The stripe width, furthermore, can be varied by using the optical system shown in Figure 3 or by adjusting the laser output, and therefore, multiple TFT rows can be formed within a single stripe in a case where the stripe width is enlarged as well. In other words, the circuit constitution of a 10-inch LCD is designed in such a way that a single scanning line and a drive circuit for driving it will be confined within a width of 60-80 μm, and as a result, said single scanning line and drive circuit can be formed within a singular striped poly-Si layer.

[0025]

The interval between scanning lines is approximately 150-250 μm, and therefore, two scanning lines and [a] drive circuit can be formed within a singular striped area by adjusting the stripe width within a range of 200-350 μm. In such a case, the throughput is twice as high as that of the prior art.

[0026]

As has been mentioned above, a TFT with high performances can be obtained not only homogeneously but also in a high throughput by obtaining a striped poly-Si layer by using a laser beam which has been rectified in such a way that its intensity distribution would be homogenized.

[0027]

The mobility and homogeneity of the TFT obtained in the aforementioned method were 100 cm/vs and ±10%, respectively. Thus, high performances were exhibited. Moreover, the throughput

can also be improved by enlarging the stripe width. If a circuit is thus constituted within a stripe, a high laser-annealing efficiency can be achieved, accompanied by an improved throughput, and a TFT with high and homogeneous performances can be obtained.

[0028]

(Effects of the invention)

As has been mentioned above, a striped poly-Si layer which serves as an active layer with a homogeneous crystallinity can be obtained in the method of the present invention for preparing a TFT above a glass substrate by means of a low-temperature process by using a CW laser with a homogeneous intensity distribution for annealing purposes.

[0029]

If a mask is designed in such a way that a transistor will be formed within this stripe, a poly-Si TFT with high and homogeneous performances can be obtained. If the laser-annealing area is confined to the LCD circuit unit (drive circuit unit for pixels corresponding to a single scanning line) alone, the throughput can be improved, and a drive circuit-integrated LCD with a large area can be efficiently prepared.

/4

Brief explanation of the figures

Figures 1: Diagrams which show cross-sectional views of the individual processes for manufacturing the TFT of the present invention.

Figures 2: Diagrams which show plane views of the individual processes for manufacturing the TFT of the present invention.

Figure 3: Demonstrational diagram pertaining to an optical system employed in the present invention.

Figure 4: Diagram which shows the beam intensity distribution on the irradiation plane.

Figure 5: Demonstrational diagram pertaining to the optical system employed in the second application example.

Keys to Figures:

Figure 4

[(1): Intensity; (2): Position]

Figure 5

[(1): Intensity; (2): Position]